108-106USA000



12

FoV (10)

4 Moving Gate
Code Structure

7A

7B

FoV Limits

6A

3

B

8

2

FIG 1A

folding mirror

7A

8 (optical Bench)

299

10

7A

3A

3B

6B

299

7B

FIG. 1B1

1A

(1) Fixed focal length camera lens
(2) Fixed focal distance

Module housing

Linear (1D) detector array

3A

3B

3

$X_{FS}$

$Y_{FS}$

$Z_{FS}$

6A

7A

66Z

9

10

4

6B

7B

66Z

11A  11C  11F

1A

Planar laser illumination beam undergoes micro-movement

FIG. 1B2.

FIG.1C

FIG.1D

FIG.1E1

FIG.1E2

$I(y_c) = $ gaussian

Beam width (w)

maximum object range

FIG.1F

FIG 1G1

FIG. 1G2

FIG.193.

FOV Limits

FOV of a single pixel

FOV Limits

FIG. 164.

25

20"

1m4

CCD Fov limits

1m3          1m3    3.5   8"

10

1m4

tallest    22"
look
level

10

36"

belt
level

42"

* Fixed Field of Field

FIG. 1G5

FIG. 1G6



FIG. 1G7

32A

6A,6B

32B

16  13  FIG. 1G 8

14  14B

L bracket

VLD sticking
out of block

13

32A

2.000"

32B

14
block

cylindrical lens
16

2.000"

FIG. 1G.9

11

3.550"  3.275"  2.675"  2.075"  1.475"  .875"  .575"  .000"

16

14B

14

11

13

32A

32B

FIG. 1G 10

.750"

.540"

1.237" H

.861"

13

14

16

FIG. 1G11

.550"

13

14

16

Ø.394"

FIG. 1G12

R<0.5% (760—800nm)
over zone ø4.3
50/5x0.063;C1x0.4;C1x1.6

R<1% (760—800nm)
over zone ø4.8
50/5x0.063;C1x0.4;C1x1.6

ø4.8 +0.01

ø5.5 0 -0.7

ø5.5 0 -0.03

6.5 mm

S/RO.5

2.5±0.1

(1.41)

$\frac{V}{S}$ See*:K5x0.018

**FIG. 1G 13**



Testzone ø4.3

**FIG. 1G 14**

FIG. 1G15A    FIG. 1G15B

furthest object/working distance

FIG. 1H1



FIG. 1H2

**Image distance vs object distance**



FIG. 1H3



FIG. 1H4



FIG. 1H5

Eccd = CCD irradiance
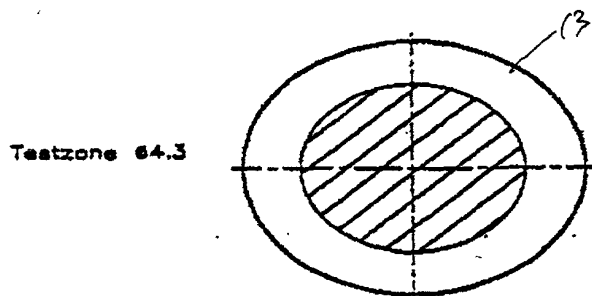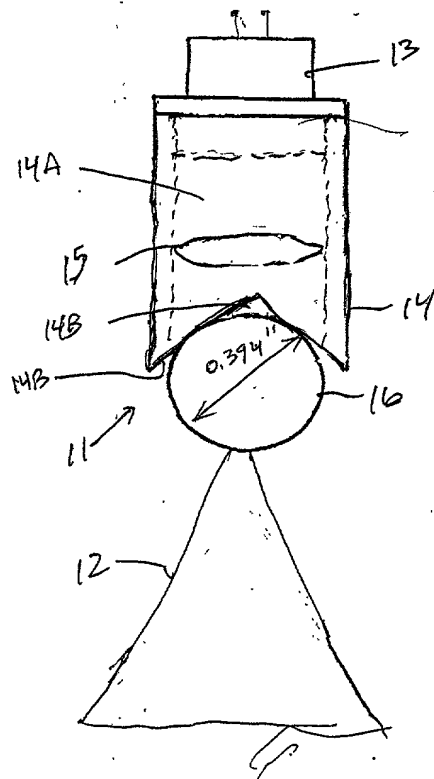(in Watts / meter squared)

d = dimension of CCD Pixel

D

ri

f = Lens Focal Length
F = Lens f-stop
ri = Image distance
ro = Working distance
m = Lens Magnification

ro

**Assumptions:**
1) Objects are Lambertian Scatterers
2) Object Reflectance = 100%
3) Optical Transmittance = 100%
4) Square CCD pixels

Eobj. = Evenly distributed irradiance
(in Watts / meter squared)

do = dimension of CCD Pixel projected
onto the object plane

CCD-Based Scanner

*FIG. 1H6*

FIG. 1I1

FIG. 11.2A

Prior to object Illumination

(SPMF)

### The First Generalized Speckle-Noise Pattern Reduction Method Of The Present Invention

Prior to illumination of the target with the planar laser illumination beam (PLIB), modulate the spatial phase of the transmitted PLIB along the planar extent thereof according to a spatial phase modulation function (SPMF) so as to modulate the phase along the wavefront of the transmitted PLIB and produce numerous substantially different time-varying speckle-noise patterns at the image detection array of the IFD Subsystem during the photo-integration time period thereof. — A

Temporally average the numerous substantially different time-varying speckle-noise patterns produced at the image detection array in the IFD Subsystem during the photo-integration time period thereof, so as to thereby reduce the power of the speckle-noise pattern observed at the image detection array. — B

## FIG. 1I2B

22/206

6A

305

array #1

array #2

14

16

302

300

22

303A, 304B

301B

$f_{osc.} \simeq 20\,KHZ$

307

**FIG. 1I3A**

301A

301B

**FIG.1I3B**

307B

305

307A

306

**FIG. 1I3C**

304A

303A

$\tilde{V}(\omega t - \pi/2)$

301A

301B

303B

304B

302

$V(\omega t)$

**FIG. 1I3D**

Figure 1

FIG. 1I3E

FIG. 1I3F



FIG 1I3G

6A →

311A (HOE)

← 310

14

16

22

← 315

$f_{osc.} \cong 20\,KHz$

FIG 1I4A

array#1

311A

31B

holographically - fabricated
cylindrical lens array

FIG. 1I4B

array#2

316

318B

318A

FIG 1I4C

dual HOE array

314A

314B

313A

313B

311A

311B

$V(\omega t - \pi/2)$

$V(\omega t)$

312

FIG. 1I4D

6A, 6B

324B
326A
329
322
321

Reflection-Based
PLIB
micro-oscillator
array

14
16
324A
+
~
323

331
331
331

$f_{osc} \cong 20 KHZ$

## FIG. 1I5A

322
325A
324A
327
324B
326A
326B
330B
330A
325B
328
329

## FIG. 1I5B

325A
324A
325B
330A
322
14
16
329
323

## FIG. 1I5C

325A
324A
325B
14
16
~

## FIG. 1I5D

Beam Deflection
Control Signals
To Acousto-optic
Bragg Cell
Panel

*FIG. 1I6A*



Beam deflection
Control Signals
To Acousto-optic
Bragg Cells

*FIG. 1I6A*

6A,6B

365

363

360

361

piezo-electric
driven
deformable
mirror (DM)
structure

14

16

362

fosc.

367

mirco-oscillating
Planar Laser
Illumination Beam

364

fosc. ≥ 30 KHZ

Drive
CKTry

22

FIG. 1I7A

365

366A

366B

366C

362

FIG 1I7B

365

367

(364)
deformable
mirror (DM)
structure

13

14

16

362

Drive
CKTry

366

22

FIG 1I7C

6A,6B

14

16

372    371

370

374 phase modulation disc

FIG. 1I8A



ΦLIA

371

370    6A    m    ω

22    occ    375

374

FIG. 1I8B



370

14
16

372

375

373

374

371

FIG. 1I8C

FIG. 118E

E-field is sum
of E-field from
each lenslet

Target
object

10-100mm

374

371

13
14
16



FIG. 118D

PLIB

6A,6B

6"

376

376

374

6A,6B

701

706

22

703

700

702

14

16

705

701

704  703

"Phase-only LED-Based
Phase modulation
Panel"

FIG.1I8F

13

15

6A,6B

16

702
701

705

708

704
703

706

22

FIG.1IG

FIG. 117A

optical specifications:

- 30 cylindrical lens (lines) per linear inch
- focal length ≈ 2.0 millimeters
- diameter of lenticular carousel ≈ 4 inches
- acrylic material
- lenticular cylindrical elements on inside diameter

FIG. 119B

FIG. 1I10A

optical specifications:

- 30 cylindrical lens (lines) per linear inch
- focal length ≈ 2.0 millimeters
- diameter of lenticular carousel ≈ 4 inches
- acrylic material
- lenticular cylindrical elements on inside diameter



FIG. 1110B

FIG. 1IIIA

FIG 1I/1B

FIG. 111C

Second Generalized Method of
Reducing Speckle-Noise Patterns
at Image Detection Array
of the IFD Subsystem (3)

(TIMF)

FOV(10)

MOVING BAR CODE
STRUCTURE
4

12

7A

7B

6A

TIMF

3

6B

TIMF

2

5

8

1

FIG.1I12

FIG. 1 I 13A

## The Second Generalized Speckle-Noise Pattern Reduction Method
## Of The Present Invention

Prior to illumination of the target with the planar laser illumination beam (PLIB), modulate the temporal intensity of the transmitted PLIB along the planar extent thereof according to a temporal intensity modulation function (TIMF) so as to modulate the phase along the wavefront of the transmitted PLIB and produce numerous substantially different time-varying speckle-noise patterns at the image detection array of the IFD Subsystem during the photo-integration time period thereof.

—A

Temporally average the numerous substantially different time-varying speckle-noise patterns produced at the image detection array in the IFD Subsystem during the photo-integration time period thereof, so as to thereby reduce power of the speckle-noise pattern observed at the image detection array.

—B

FIG. 1I13B

FIG. 1 I14A



FIG. 1 I14B

optically - resonant
wavefront modulating
cavity
430

6A,6B

432

433

431

14

435

16

431

## FIG. 1I15A

6A,6B

13

436A

433

437

15

436B

14

16

434

432

437

435

## FIG. 1I15B

44/206



TIM Controller
447
22
13'
Temporal
Intensity
modulation
Control
Signals
14
16
442
443
441
441

mode-locked laser diode
(MLLD) array

FIG. 1I15C



447    22

L

$f_{mlB} = \frac{c}{2L}$

444    445

Multimode
Diode laser cavity
(InGaAsP) DT

Collimating Lenslet

Active
mode locker    446
(Temporal
Intensity
modulator)

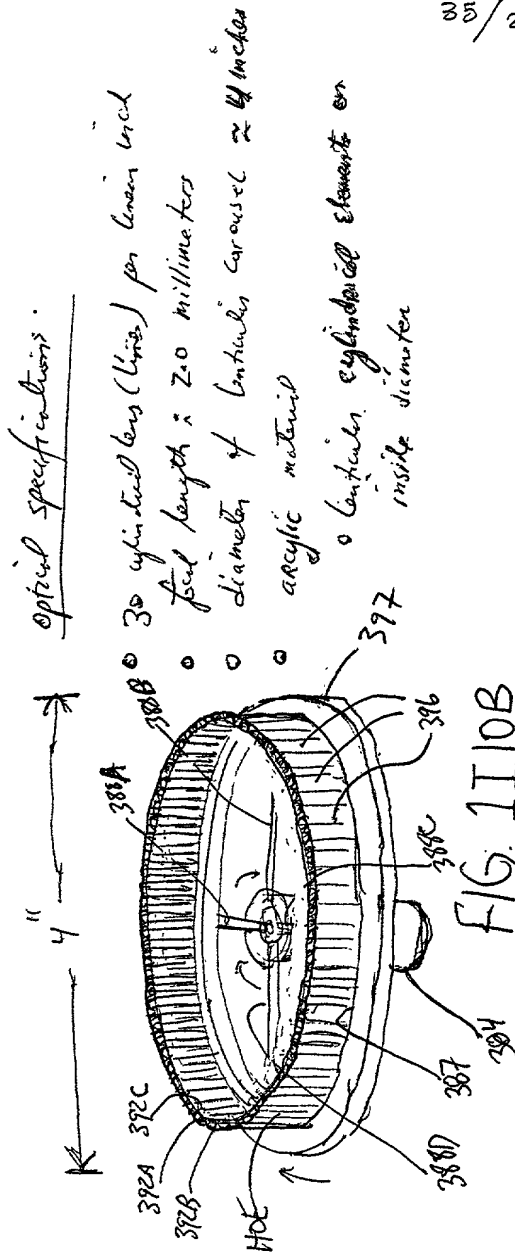448
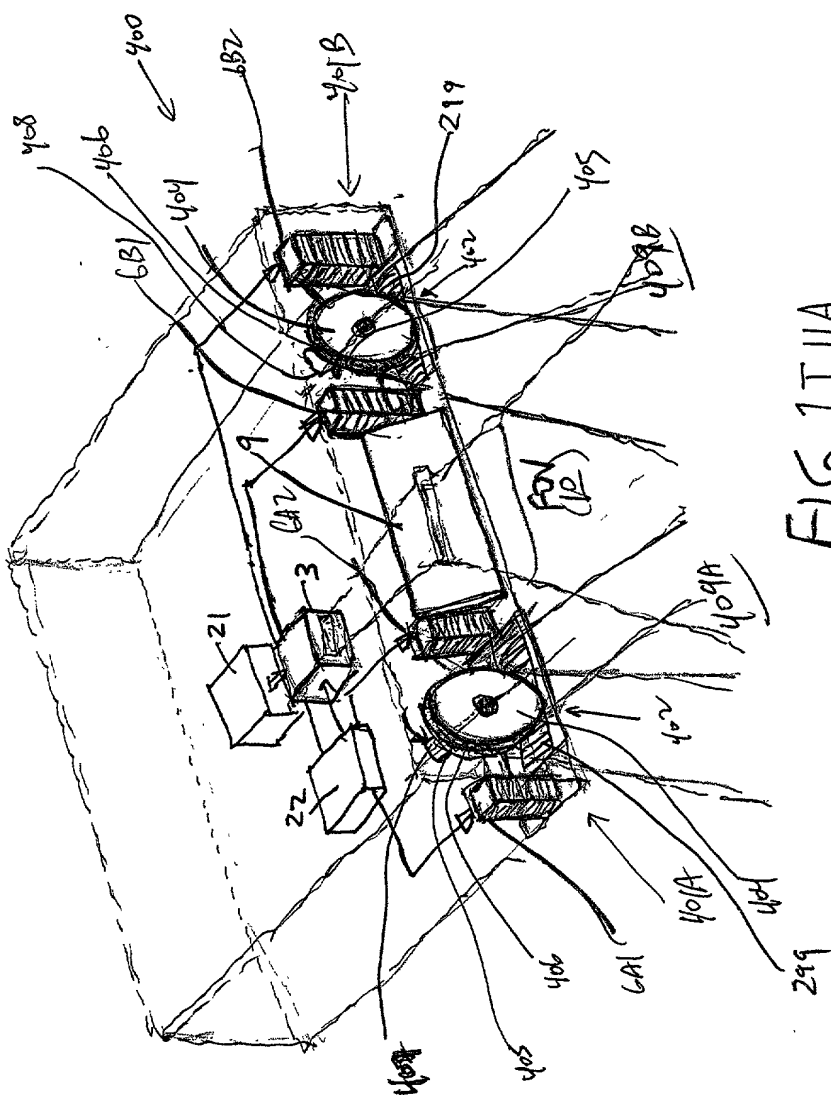Passive Mode locker
(saturable absorber)

449
Mirror

13'

FIG. 1I15D

FIG. 1116A



FIG. 1116B

Third GENERALIZED METHOD
of Reducing Speckle-noise
Patterns At Image
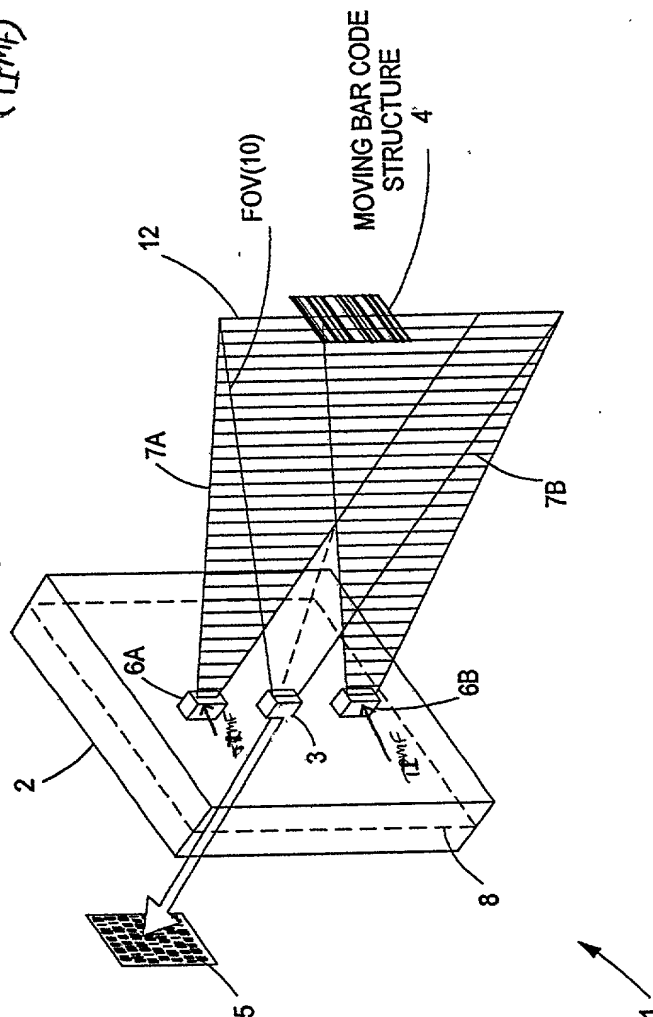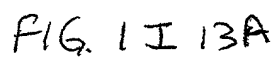Detection array of the
IFD Subsystem (3)

(S/MF)

FOV(10)

12

7A

7B

6A

S/MF

3

S/MF

6B

2

8

5

1

MOVING BAR CODE
STRUCTURE
4

FIG F17

SIMF

FIG. 1.118A

Prior to object Illumination

### The Third Generalized Speckle-Noise Pattern Reduction Method
### Of The Present Invention

Prior to illumination of the target with the planar laser illumination beam (PLIB), modulate the spatial intensity of the transmitted PLIB along the planar extent thereof according to a spatial intensity modulation function (SIMF) so as to modulate the phase along the wavefront of the transmitted PLIB and produce numerous substantially different time-varying speckle-noise patterns at the image detection array of the IFD Subsystem during the photo-integration time period thereof.

— A

Temporally average the numerous substantially different time-varying speckle-noise patterns produced at the image detection array in the IFD Subsystem during the photo-integration time period thereof, so as to thereby reduce power of the speckle-noise pattern observed at the image detection array.
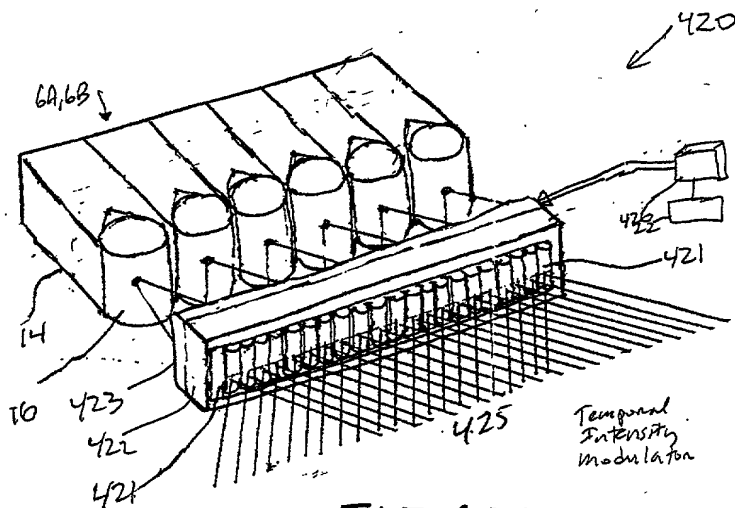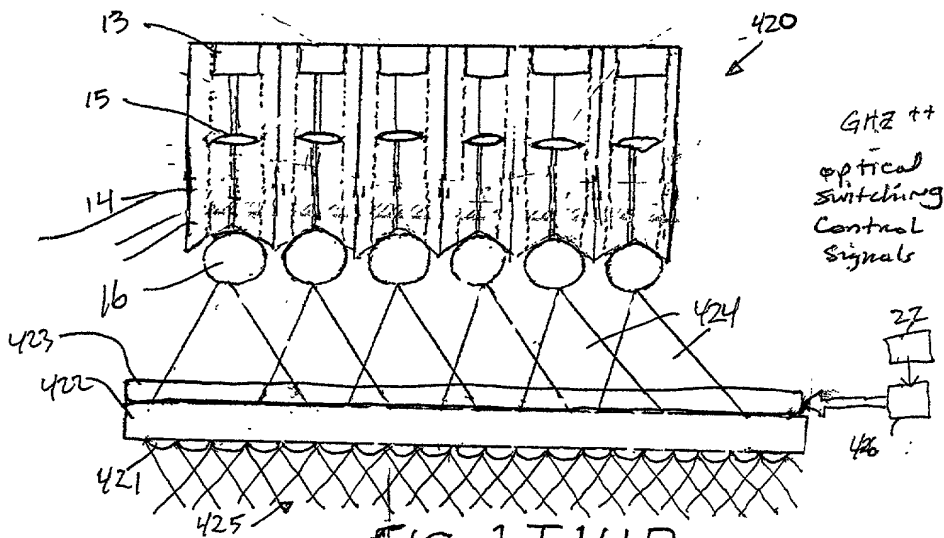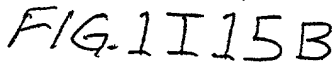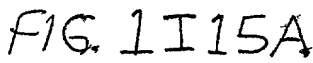
— B

FIG. 1I 18B

FIG. 1 I 19A



spatial intensity modulation screens

FIG. 1 I 19B



FIG. 1 I 19C
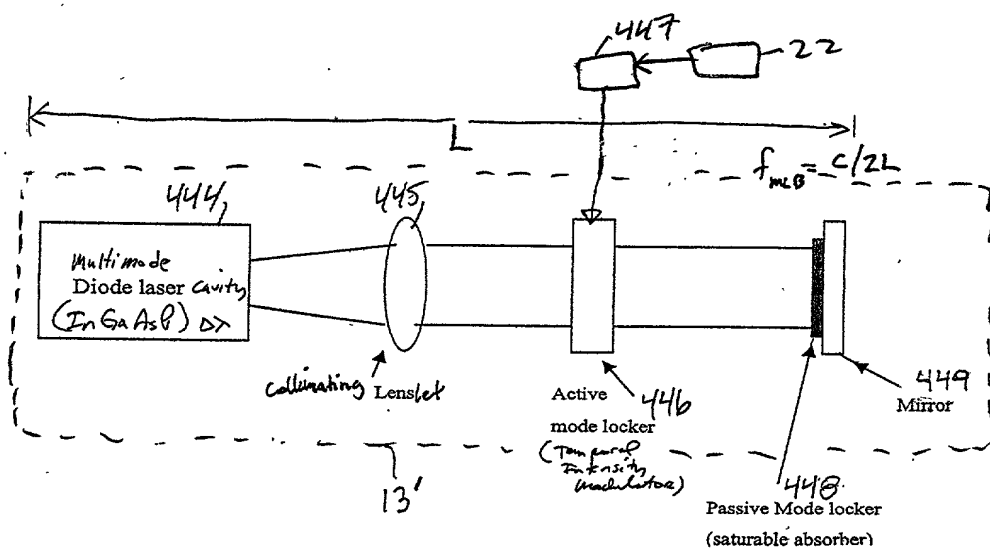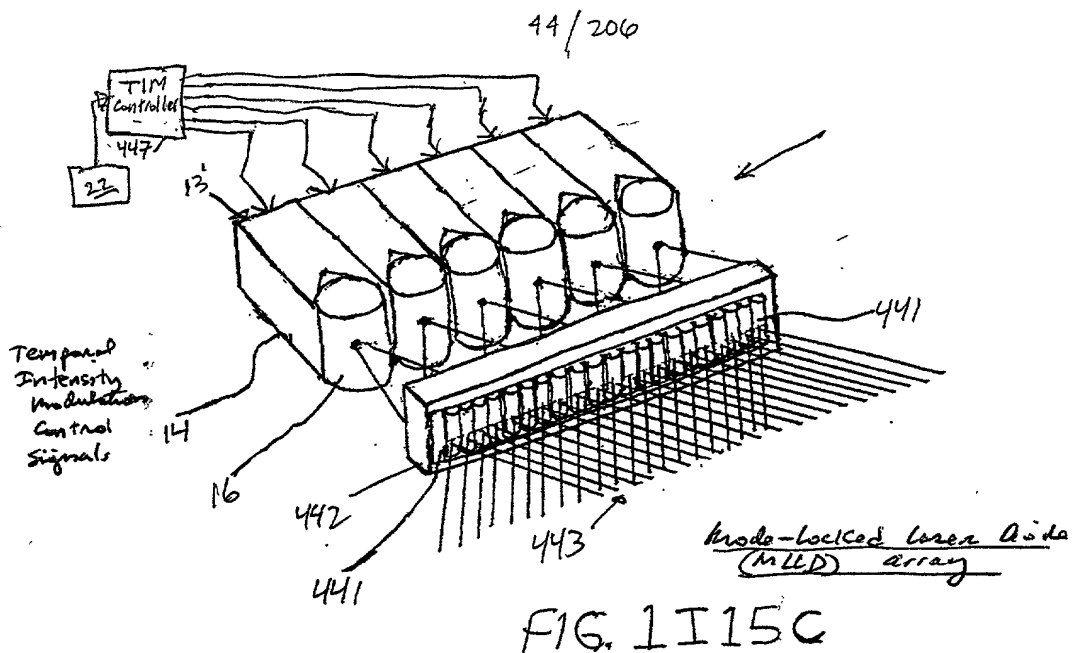


FIG. 1 I 19D

Fourth Generalized method of
Reducing Speckle-Noise Patterns
at Image Detection array
of the IFD subSystem

(SIMF)

12

FOV(10)

MOVING BAR CODE
STRUCTURE
4

7A

7B

6A

6B

SIMF

3

2

8

5

1

FIG. 1I20

FIG. II 21A

### The ~~Fourth~~ Generalized Speckle-Noise Pattern Reduction Method
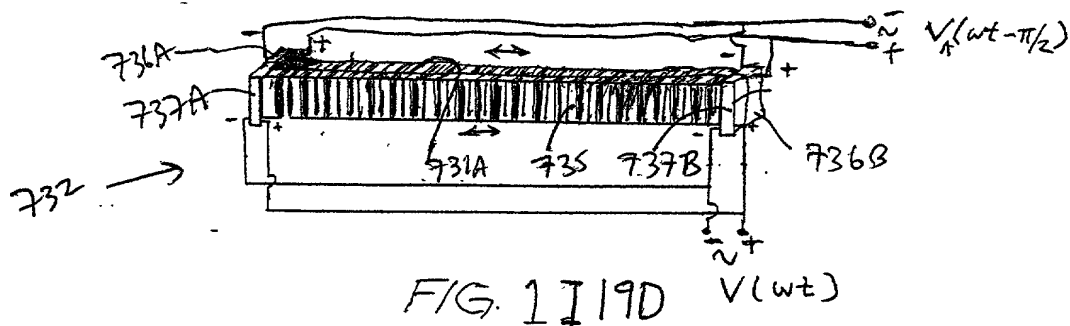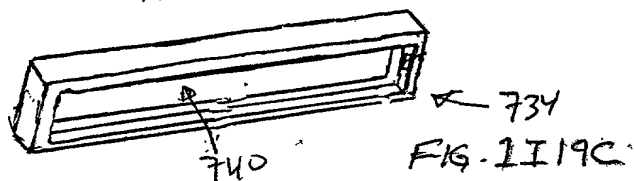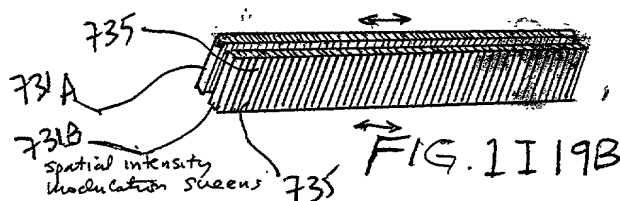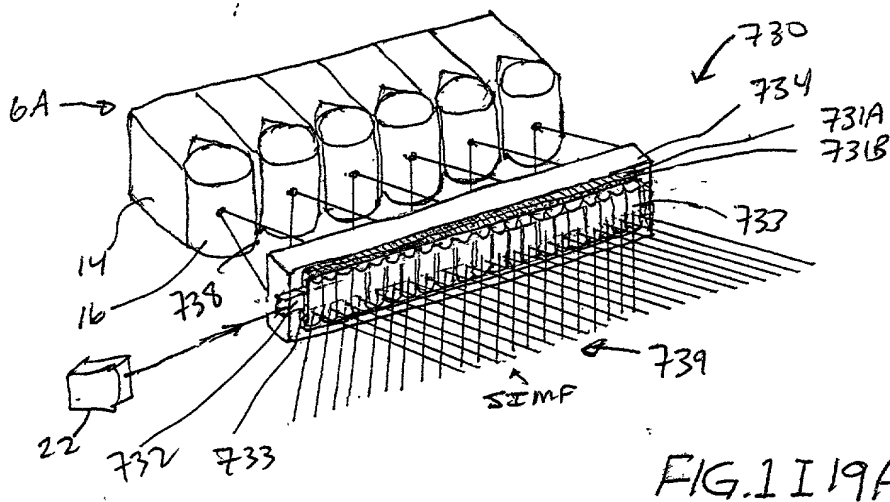### Of The Present Invention

After illumination of the target with the planar laser illumination beam (PLIB), modulate the spatial intensity of the reflected/scattered (i.e. received) PLIB along the planar extent thereof according to a spatial intensity modulation function (SIMF) so as to modulate the phase along the wavefront of the received PLIB and produce numerous substantially different time-varying speckle-noise patterns at the image detection array of the IFD Subsystem during the photo-integration time period thereof. — *A*

Temporally average the many substantially different time-varying speckle-noise patterns produced at the image detection array in the IFD Subsystem during the photo-integration time period thereof, so as to thereby reduce the speckle-noise pattern observed at the image detection array. — *B*

FIG. 1I21B

Electro-optical
Rotating
IRIS

460

464

LCDe
Drive
CKS

3A

Module
housing

3A'

3Bl

3B2

6A

299

optical
axis

6B

299

463 460

SIMF 461

4

FIG. 1IZZA



Mechanically-Rotating
IRIS

3A

Module
housing

473

474

476

Motor
Driver

478

3Bl

3B2

6A

299

optical
axis

6B

299

477

SIMF 472

471

473

4

470

FIG. 1IZZB

FOURTH DRAFT

Fourth Generalized Method of
Reducing Speckle-Noise Patterns
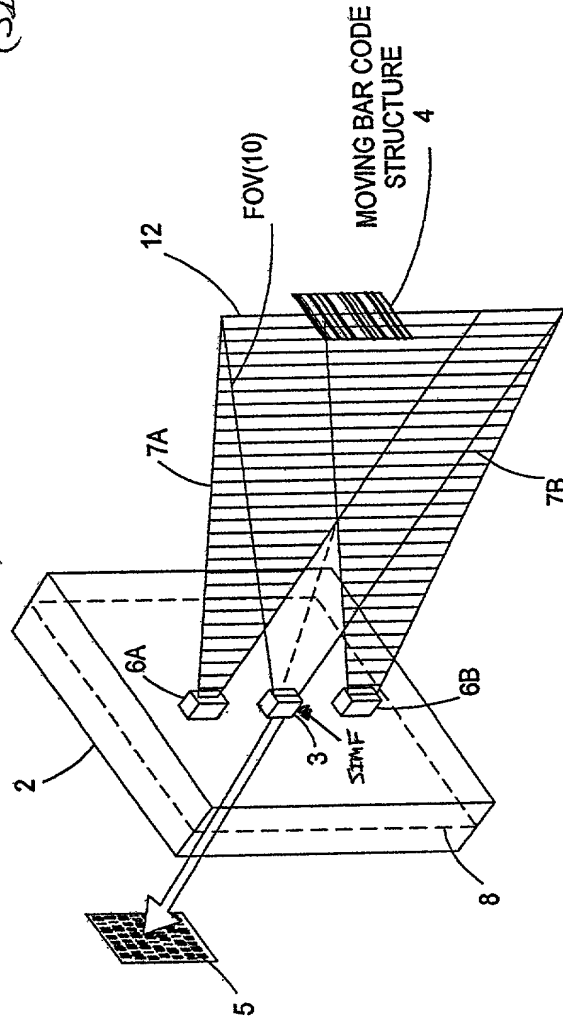at Image Detection Array
of the IFD Subsystem

(TIMF)



12

FOV(10)

7A

MOVING BAR CODE
STRUCTURE
4

7B

2

6A

3

TIMP

6B

8

5

1

FIG.1I23
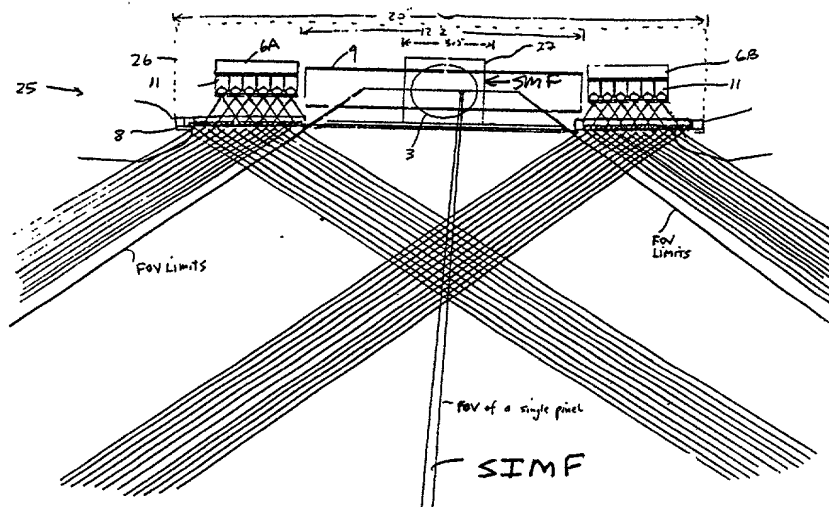
FIG.1I24A

### The Fifth Generalized Speckle-Noise Pattern Reduction Method
### Of The Present Invention

After illumination of the target with the planar laser illumination beam (PLIB), modulate the temporal intensity of the reflected/scattered (i.e. received) PLIB along the planar extent thereof according to a temporal intensity modulation function (TIMF) so as to modulate the phase along the wavefront of the received PLIB and produce many substantially different time-varying speckle-noise patterns at the image detection array of the IFD Subsystem during the photo-integration time period thereof. ___A
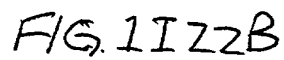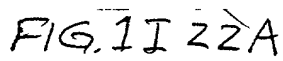
Temporally average the many substantially different time-varying speckle-noise patterns produced at the image detection array in the IFD Subsystem during the photo-integration time period thereof, so as to thereby reduce the speckle-noise pattern observed at the image detection array. ___B

FIG. 1I24B

FIG 1I25

Fixed focal Length lens
Cases



camera
camera lens
fixed focal length imaging lens
Camera FOV limit
Boxes, etc
scan field

FIG 1K1

Conveyor 34



fixed focal length imaging lens

Scan field
Envelope packages
Conveyor 34

FIG. 1K2

9B  9D  9E

FOV (of
linear camera,
shown edge on)

3

3B

9A

9C

FIG. 1L1

22

3B

35

10

9G

3

FOV

FIG. 1L2

Pixel power density vs. object distance (general example)

FIG-1M1

Near and far object distance laser power distribution data and curve fit

| | |
|---|---|
| ○ | near object distance data |
| —— | near object distance fit |
| △ | far object distance data |
| —— | far object distance fit |

Power (micro W)

350

300

250

200

150

100

50

0

-1          -0.5          0          0.5          1

Position along planar laser beam width (m)

FIG. 1M2

**Planar laser beam width vs. object distance**

FIG. 1M3

Figure 4: Planar laser beam height vs. object distance (far object distance focus)

FIG /M4

**Center line power density vs. object distance (far object distance focus)**



FIG. 1N

Figure 6: Pixel power densities vs. object distance



FIG. 10

lateral extent of field of
view which must be
covered
Near Field

results of summing contributions
from all VLDS

Far Field

individual
VLD
contributions

FIG.1P1

FIG 1P2

FIG. 1Q1

fixed focal length/fixed focal distance

IFDM

VLD Driver

VLD Driver

VLD Driver

VLD Driver

VLD Driver

VLD Driver

Camera Control Computer

Image Grabber

Data Buffer

Image Processing Computer

1B

FIG.1Q2

FIG.1R1

Fixed Focal Length/Fixed Focal Distance

IFDM

3B

3A

Stationary

37A

70/206

37B
Stationary

18

VLD Driver

18

VLD Driver

18

VLD Driver

6A

6B

18

VLD Driver

18

VLD Driver

18

VLD Driver

19

Image Grabber

Camera Control Computer

22

20

Data Buffer

21

Image Processing Computer

3

1C

FIG. 1R2

FIG.1S1

72/206

FIG. 152

1D

Fixed Focal length/ Fixed Good
(distance)

FFDM
stationary
9

3B

3A

18

VLD Driver 8

VLD Driver 8

18

VLD Driver 8

6A

12

37A
stationary

18

211

19

Image Grabber

20 Data Buffer

21 Image Processing Computer
with VRAM

22 Camera Control Computer

18

VLD Driver

18

VLD Driver

18

VLD Driver

6B

37B
stationary

stationary

211

Package

Application:
— Bottom scanner

FIG. IT

FIG. 1U

Plane of
Laser
Illumination

FOV(10)

Applications:
• Hand-Held Scanner
• Presentation Scanner

FIG. IVI

FIG. 1V2

Fixed Focal length/fixed Focal distance

FFDR

9'

38

37A'
(with switch moving mirrors)

39A

77/206

37B'

39B

34

33

VLD Driver

VLD Driver

VLD Driver

6A'

VLD Driver

VLD Driver

VLD Driver

6B'

18

18

18

18

18

18

11

11

27'

8

27'

Camera

Central Computer

22

19

Image Grabber

Data Buffer

20

Image Processing Computer
w/ VRAM

21

3'

1'

FIG. IV3

FIG. 1V4

Moving Plane of Laser Illumination 12'

12'

Moving (up)

12

6A

37A'

2gg

18'

19

22

20

I

21

3B

3A

2gg

37B'

6B

18

- Hand-held Scanner
- Presentation Scanner

1'

HOST
SYSTEM

(Presentation type scanner)

FIG. 1 V5

80/206

FoVlimits 10

12

moving bar code structure 4

stationary planar laser illumination beam 12

FIG. 2A

40

FIG. 2 B1

82/206

optical axis

FIG. 2B2

(1) Focal length axicon lens
(2) Vmarks & focal distance

FIG. 2C1

- fixed focal length imaging lens
- variable or Dynamic focus control

3B'
3A1
3A
3D
3C
3E
22
3'

FIG. 2C2

FIG. 2D1

Fixed Focal length/
Variable of
dynamic
Focus control

Stationary

Stationary

Camera Control Computer

Image Grabber

Data Buffer

Image Processing Computer

VLD Driver

FIG. 2D2

• fixed focal length imaging lens
○ variable or dynamic
  focus control

3B'
3A'
3A
3B
3D
3c
3'
3E
22

FIG. 2D3

FIG. 2E1

FIG. 2E2

fixed focal length/
variable or
dynamic focus
Control

3B'

3A

12

Stationary
37A

37B
Stationary

18

18

18

VLD Driver

VLD Driver

VLD Driver

VLD Driver

VLD Driver

VLD Driver

279

279

11

11

18

18

6A

6B

18

Camera
Control
Computer

22

19

Image
Grabber

20

Data
Buffer

21

Image
Processing
Computer

3

40C

- fixed focal length imaging lens
- variable or dynamic focal control

3B'

3A

3A1

3C

3C

3'

3

3D

22

FIG. 2E3

FIG. 2F1

FIG 2F2

- fixed focal length imaging lens
- variable focus or dynamic focus control

3B

3A1

3A

3D

3C

3E

22

3

FIG.2F3

Top Conveyor Scanner:
- fixed focal length imaging lens
- variable focal distance control

Side Conveyor Scanner:
- fixed focal length imaging lens
- dynamic focal distance control

40

40

FIG. 2G

95/206

Composite
Plane of
Laser
Illumination

FOV

12

40C

21

20

22

19

18

37A

29, 6A

1B

37B

6B

29

3A

38

FIG. 2H

Applications:
· Hand Held Scanner
· Presentation Scanner

FIG. 2I1.

FoV limits

7A

6A

3

6B

7B

FoV 10

12'

Stationary Bar Code Symbol

Moving Plan Laser Illumination Beam 12

3-D Scanning Region

1

2

8

5

40

3'

6A

3B

299

2

37A

6B 299

37B

9'

7A

40'

7B

4

12'

FIG 2I2

3-D
Scanning
Region

9

3B'

3A'

3'

joint ly moving mirrors

37A'

299

37B'

99A

99B

18

VLD Driver

VLD Driver

VLD Driver

VLD Driver

VLD Driver

VLD Driver

6A

6B

18

System Controller

22

Image Former

19

Data Buffer

20

Data Image Processor

21

4'

FIG.2I3

- fixed focal length imaging lens
- variable or dynamic focus control

3B'
3A'
3A
3D
3
3C
3E
22

FIG. 2I4

FIG. 2I5

Labels visible in figure: 40', 20', 22, 19, 18', 9', 37A', 6A, 21, 18', 37B', 2', 6B, 3A, 3B', 12', Plane of Laser Illumination, FOV limits 10

40

HOST
SYSTEM

FIG. 2I6

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velocity

moving bar
code
structure.

FOV limits

12

10

7A

7B

6A

3

6B

2

8

5

50

FIG 3A

FIG. 3B1

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299 optical axis

4

6A

3B1

3B2

3A'

3A

module housing

(1) Variable Focal Length Camera Lens
(2) Variable focal distance

299

6B

FIG. 3B2

- variable Focal length imaging
  lens (Zoom)

3B" variable dynamic focal distance control

3A

12

299

18 VLD Driver

18 VLD Driver

18 VLD Driver

6A

12

299

18 VLD Driver

18 VLD Driver

18 VLD Driver

6B

19 Image Grabber

22 Camera Control Computer

3

20 Data Buffer

21 Image Processing Computer

3D A →

Fig 3C1

FIG. 3C2

- Variable focal length camera lens
- variable focal distance ⊙

Variable focal length (zoom) control  3A1

3A

3B1

Variable or dynamic focus control  3B2

3D

3C1

3C2  3C2

3E1

3"

motor 43

42

3''

±18mm

3B1 zoom lens

stationary lenses 3A1

3A (image plane)

object plane

focal distance lens (3B2)

CCD Image Detection Array

(image Plane)

±6MM

44

45

FIG. 3D1

3A1

3A

412

411

45

410

401B

416

404

403

400

413

405

407  401A  408

FIG 3D1

3B''

3A1

3B''

401B

414

416

405

412

415

404

3A

403

413

401A

408  406

400

402

407

FIG 3D2

FIG 3E1

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FIG.3E2

'50B ⟶

Variable or dynamic
Focus Control
3B2

Variable focal length
(Zoom) Control 3B1
3A1
3A

3D

3B2

3C1

3C2

3E1

3E2

22

3"

FIG. 3E3

FIG.3E4

FIG. 3E5

FIG. 3E6

FIG. 3E7

\*variable FOV



FIG. 3E8

6A  3"  37A
6B
299
299
37B
37A
7A
3B
10
50C
7B
12

Stationary Planar Laser Beam

FIG. 3F1

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FIG. 3F2

FIG. 3F3

FIG. 3G1

120/206

FIG. 392

50D —

FIG. 3G3

- variable focal length imaging lens
- variable focal distance

- variable focal length imaging lens
- dynamic focal distance

FIG. 3H

Composite Plane of Laser Illumination

12

FoV Limits (10)

50D

21

20

22

19

18

9

299

37A

6A

3B"

3A

299

6B

37B

18

FIG. 3I

FoV limits
10

12'

3-D
Scanning
Region

4
stationary bar code
structure

moving planar
Laser illumination
Beam 12'

7A

6A

3

6B

2

8

5

50

FIG. 3T1

Mechanical oscillator

3-D Scanning Region

FIG. 3J2

FIG. 3J3

Variable or dynamic focus Control (3B2)

Variable focal length (Zoom) Control (3B1)

3A1

3A

3D

3C2

3C1

3E2

3E1

22

3"

FIG. 3J4

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Composite
Plane of
Laser
Illumination 12

FOV
Limits (10)

12

3B"

3A

6B

37B'

18'

299

6A

37A'

37A

18'

19

22

22

SD'

21

299

FIG. 3T5

Applications:
• hand-held Scanner
• Presentation Scanner

50'

2-D
Hold-under
Scanner

FIG-3J6

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Stationary
FoV (10)

moving, planar,
illuminator
Beam

FoV
Limits 10

12

7A

6A

55

6B

5

8

2

60

FIG 4A

FIG. 4B1

FIG. 4B2

(1) Fixed focal length camera lens
(2) Fixed focal distance

60A

11A

6B

299

57B

55A / 55

SSA

132/206

6A

299

57A

10' FOV Limits

55B

optical axis

microoscillation of planar laser illumination beam components

133 / 206

Fixed focal length
Fixed focal distance

55B

55A

55

57B

50B

57A

50A

299

11

VLD Driver

18

6A

6B

19

Image Buffer

Data Buffer

20

Image Processing Computer

21

Camera Control Computer

22

10

8

60A

FIG. 4B3

FIG. 4CL

FIG. 4C2

135/206

60

2-D
Hold-under
scanner

FIG. 4D

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Plane of
Laser
Illumination

FoV
Limits
10

Applications:
• Hand-held Scanner
• Presentation Scanner

FIG. 4E

FIG. 5A

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FOV(10')
Limits

moving Planar Laser Illumination Beam

(12')

FIG 5B1

(1) Fixed focal length zoom lens
(2) Variable focal distance

57A
6A
299

X

140/206

SS'
SSA
y

SSB

(FOV)
10'  optical axis

299
6B
57B

70A

FIG. 5B2

Low-resolution 61A
CCD

Short focal length lens

61B - Fixed focal length / variable focal distance

55B

61

62

Image Grabber

High-Resolution CCD array

55A

55'

VLD Driver

18

299

11

8

6A

6B

69

242

57A

58A

57B

58B

Camera Control Computer

22

19

Image Grabber

Data Buffer

22

Image Forwarding Computer

21

70A

FIG. 5B3

- Fixed focal length imaging lens
- Variable focal distance control

55B2
55B1
55A
55D
55C
55E
22
55

*FIG. 5B4*

6A
9
299
58A
5B'
57A
55B'
7A
55'
299
57B
6B
58B
7A

70B
12'

3-D Scanning Region

FIG. 5C1

(1) Variable focal length given lens
(2) Fixed focal distance

57A
6A
11F
11A
55A
55
55'
299
9
4

11F
6B
11A
299
57B
70B →

FIG. 5C

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FIG.5C3

- fixed focal length imaging lens
- variable focal distance control

55B2
55B1
55A
55D
55C
55E
55'
22

FIG. 5C4

FIG. 5D

(12') moving Planar Laser Illumination Beam

stationary FoV(10')

FIG. 6A

86

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55"    3A

6B    57A    58A

57B    55B"

6A    7A

299

80A

299

58B

7B

FIG. 6B1

6A

57A

299

SS''

SSB'

SSB

SSA

55''

11A

6B

57B

299

(1) Variable focal length zoom lens
(2) Variable focal distance

80A

FIG. 6B2

FIG. 6B3

Variable focal distance Control
55'B2'

Variable focal length (Zoom) Control 55B2

55B1

55A

55D

55E1

55C1

55C2

55E2

55"

22

FIG. 6BH

FIG. 6C1

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(1) Wave focal length curve lens
(2) Variable focal distance

FIG. 6C2

155/206



FIG. 6C3

61A 61B
17
55B"
9 stationary
57A
57A
58A
299
11 11 11
55A
VLD Driver
18
VLD Driver
18
VLD Driver
18
5A
58B
57B
57B
299
11 11 11 11
18 18 18
6B
62
Image grabber
19
Image Grabber
Camera Control computer
22
55"
20
Data Buffer
21
Image Processing computer
80B

Variable food distance Control

SSB2

Variable food length (Zoom) Control (SSB3)

SSB1

SSA

SSD

SSC1

SSE1

SSC2

SSE2

22

SS "

FIG. 6C4

80

FIG. 6C5

10'

7B

29B'

57B

58B

299

6B

28

29A'

7A

57'

57A

9

58A

21

299  6A

500

8

501

26

25"

FIG. 6D1

FIG. 6D2

FIG. 6D3

25"

26    housing    6A

(57A)
Planar Laser
Illumination
Beam folding/
Sweeping Mirror

FOV
Folding
Mirror
(9)

4.130    10.817

3.500

CCD FOV
(10')

21    8    55"    299    58A

22

Limits of
Stationary
3-D FOV
(10')

12'

Limits of
SWEPT
Planar Laser
Illumination
Beam

FIG. 6D4

variable FOV



FIG. 6D5

2D FOV is
movable in 2-dimensions

FIG 6E1

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FIG. 6-2

6A

11A

57A

92

4

91B

55"

55A

x

y

55B

91A

8

57B

11A

6B

69

90

(1) Master focal length same lens
(2) Variable focal distance

FIG. 663

55"  55B"  ← 90

91A

91B

10'

3-D scanning Region

10^F (projected)

FIG. 6E4

100

22  18  3A  6A
103
19
20
FOV 10"
18  7A
101
21
6B
102
holographic
imaging
disc  7B
Convey
Surface

Holographic PLIIM
System employing
Linear-type CCD Image
Detector

FIG. 7A



6B
3A  101  12
100
10"

FIG. 7B

102

22  18
6B  55A
6A
37A'
19
20
18
37B'
102
101
3-D FOV

Holographic PLIIM
System employing
Area-Type
CCD Image
Detector
100'

FIG. 8A



6B
55A
37B'
102
101

12' Swept
Planar Laser
Illumination
Beam

3-D FOV
100'

FIG. 8B

**1-D CCD SCANNER EMBODIMENT**

FIG. 9

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FIG.10

120

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FIG. 11

FIG. 12A

FIG.12B

power supply    master controller    LDIP PC (512)    VLD rack
                                                          6A
                                              main optics bench (510)
power supply
                    motor
Connectors          3"    lens              camera folding mirror
Connector                                      9
bracket    Camera
Power supply
Power supply        motor
                    motor controller
                                              6B
power supply    Connectors    Camera control computer (22) and image processing computer (21)    VLD rack

FIG. 12C

main optics bench
(510)

VLD(521B)

LDIP optics bench
(520)

163
LDIP
folding
mirror

GA

collector
526

525
APD

524
lens

522
polygon

lens
527

9

collector
523

APD
528

6B

VLD 521A

hard drives
and LDIP
controller
card
529

FIG. 12D

FIG. 12E

(..main optics)
( lens groups)

FIG. 13A

540

FIG. 13B

541A

541B

540

542

540

543

FIG. 13C

## PLLIM-BASED PACKAGE IDENTIFICATION AND DIMENSIONING (PID) SYSTEM



FIG. 14

# LDIP REAL-TIME PACKAGE HEIGHT PROFILE AND EDGE DETECTION METHOD

A — Raw data is received every 5ms; plus time stamp

B — Convert raw data into range profile
R=f(int. phase], referenced with respect to Polar Coordinate System symbolically embedded in LDIP Subsystem.

C — Use Geometric transformations
$h[i] = R[i]\sin(ang - 90)$ and
$x[i] = R[i]\tan(ang - 90)$ to convert range profile $R[i]$ into height $h[i]$ and position $x[i]$ data.

D — Obtain current package height by finding prevailing height using edge detection without filtering (Fig. 16).

E — Find the coordinates of the left and right edges of package (LPE, RPE) by searching for the closest coordinates from the edges of the belt ($X_a$, $X_b$) toward the center thereof.

F — Analyze intensity data values {R(nt)} and determine the X coordinate position range $X_{\Delta 1}$, $X_{\Delta 2}$ (in R global) where the height intensity changes (i) within the spatial bounds ($X_{LPE}$, $X_{RPE}$) and (ii) beyond predetermined height intensity data thresholds.

G — Create time-stamped data set {$X_{LPE}$, h, $X_{RPE}$, $V_B$, nT} by assembling package left-edge coordinate (LPE), current package height (h), package right edge coordinate (RPE), X coordinate subrange where height values exhibit maximum intensity changes, package velocity ($V_B$), and time stamp (nT).

H — Send hextuple data set to camera control computer.

LDIP Package Dimensioner with Integrated Velocity Detection

551

Real-Time Package Height Profiling and Edge Detection Processing Module

550

belt velocity ($V_B$)

Fig. 15

# LDIP Real Time Package Edge Detection

**A** — LPE = X[Ia]
i = Ia

**B** — RPE = X[Ib]
i = Ib

**C** — i < Ib - win?  — No

Yes

**H** — i > Ia + win?  — No

Yes

**D** — H[i] .. H[i + win - 1] > Hthres?  — No

Yes

**I** — H[i - win + 1] .. H[i] > Hthres?  — No

Yes

**E** — X[i] .. X[i + win - 1] < Xa?  — Yes

No

**J** — X[i] .. X[i - win + 1] > Xb?  — Yes

No

**F** — i++

**K** — i--

**G** — LPE = X[i]

**L** — RPE = X[i]

**M** — Exit

Xa = location of belt left edge; Xb = location of belt right edge
Ia = belt edge edge pixel; Ib = belt right edge pixel
LPE = Left package edge; RPE = Right package edge
H[] = Pixel height array; X[] = Pixel location array
win = package detection window

## FIG. 16

LDIP Subsystem (122)

Polar Coordinate System
polar $(R, \Theta)$

$(I_a, \varnothing_a)$

$R\,(I_b, \varnothing_a)$
$\alpha_{192}$

y

$h_{max}$

x

z

$x_a$

belt

$X_{LPE}$

$X_{RPE}$

$x_b$

conveyor belt

Global Cartesian
Coordinate
System

Fig. 17

## INFORMATION MEASURED AT SCAN ANGLES BEFORE
## COORDINATE TRANSFORMS

$\alpha_1 = \alpha_a$
$\alpha_{192} = \alpha_b$

$I_1, \emptyset, \quad I_2, \emptyset_2$

$I_{192}, \emptyset_{192}$

$\alpha_{192}$

$\alpha_1, \alpha_2,$
$(x,y)_{\alpha 1}$

Fig. 17A

## RANGE AND POLAR ANGLE MEASURES TAKEN AT SCAN
## ANGLE $\alpha$ BEFORE COORDINATE TRANSFORMS

Range and Polar

$R_1, \emptyset_1$ $\quad$ $R_2, \emptyset_2$ $\qquad$ $R_i, \emptyset_i$ $\quad$ $R_{192}, \emptyset_{192}$

Fig. 17B

## MEASURED PACKAGE HEIGHT AND POSITION VALUES
## AFTER COORDINATE TRANSFORMS

H [ ]
Input height after
coordinate transforms

$(x,y)_{a2}$ $\qquad$ $(x,y)_{\alpha = i}$ $\quad$ $(x,y)_{192}$

$y(\alpha_2)$
$x(\alpha_2)$

height value $y(\alpha_1)$ and
position value $x(\alpha_1)$
measured at left belt edge

Fig. 17C

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CAMERA CONTROL PROCESS CARRIED OUT WITHIN THE
CAMERA CONTROL SUBSYSTEM OF EACH OBJECT ATTRIBUTE ACQUISITION
AND ANALYSIS SYSTEM

560

Start

A — Camera Control Computer receives a time-stamped quintuple Data Set (i.e. coordinate of Left Package Edge, coordinate of Right Package Edge, height, velocity, and time-stamp) from the LDIP Subsystem and store the Data Set in a Package Data Buffer Structure having N=5 columns and M rows.

5

B — Camera Control Computer analyzes height data in the Package Data Buffer and detect the occurrence of detecting height discontinuities, and based on such detected height discontinuities, determines the corresponding coordinate position of the leading package edges specified by left-most and right-most coordinate values associated with the data set at this detected height discontinuity.

C — Camera Control Computer determines the height of the package associated with the leading package edges determined at Block B above.

N

Camera Control Computer transforms the position of left and right package edge (LPE, RPE) coordinates buffered in the deepest row of the Data Package Buffer at which the height value was determined at Block D to a Global Coordinate Reference System symbolically embedded in the conveyor belt structure beneath the LDIP Subsystem, as shown in Fig. 17.

1

D

Camera Control Computer analyzes the height values (i.e. coordinates) computed over previous raw data set processing cycles, and stored in the Package Data Buffer, and determines the "median" height of package.

2    4

K

Camera Control Computer analyzes height value in the Package Data Buffer, and determines the speed of package $(V_b(t))$.

3    6    7

Fig. 18A

185/

○ ―

**1**

Camera Control Computer detects the x-coordinates of the package boundaries based on the spatially-transformed coordinate values of the left and right package edges (LPE, RPE) buffered in the Package Data Buffer.

**4**

Yes

P ―

Based on x-coordinates of the detected package boundaries (and optionally, the subrange of x-coordinates over which maximum range "intensity" data variations have been detected by the lens data of Fig. 15) determined at Block O, the Camera Control Computer determines the corresponding pixel indices (i, j) in the Image Buffer which specify the image frame(i.e. region of interest) to be cropped from the image(s) to be subsequently captured by the IFD Subsystem.

E ―

Camera Control Computer uses Focus/Zoom Lookup Table in Fig. 21 to determine the focus and zoom lens group positions based on the height of the package determined at Block D.

F ―

Camera Control Computer transmits Lens Group Moves Commands to the IFD Subsystem.

G ―

IFD Subsystem uses the Lens Group Movement Commands to move the lens groups to their desired positions.

H ―

Camera Control Computer checks resulting positions of moved lens groups.

I ―

Camera Control Computer corrects lens group positions.

J ―

Lens groups are moved to desired positions?     No

yes     **5**

**2**     **3**     L

The Camera Control Computer uses the computed values of median package height, speed and the Photo-Integration Time Lookup Table in Fig. 23 to determine the photo-integration time parameter which will ensure that "square" image pixels are produced in captured package images (i e pixels having a 1·1 aspect ratio.)

**6**     **7**

M

The Camera Control Computer sends digital photo-integration time control signal to the CCD image detection array in the IFD Subsystem.

**5**

Camera Control Computer uses package time-stamp (nT) and package velocity ($V_p$) to determine the "Start Time" of Image Frame Capture (STIC).     ― Q

Camera Control Computer uses (i) the Start Time of Image Capture (STIC) determined at Block Q, to generate a command for starting Image Frame Capture, and also uses (ii) the pixel indices (i,j.) determined at Block P to generate commands for cropping the corresponding slice of the "region of interest" in the image being captured and buffered in the Image Buffer within the IFD Subsystem.     ― R

Camera Control Computer transmits the command generated at Block R to the IFD Subsystem.     ― S

**5**

Fig. 18B

FIG. 18B

x coordinate subrange where maximum
range "intensity" variations have been
detected

| Left Package Edge (LDE) | Package Height (h) | Right Package Edge (RPE) | Package Velocity | Time-stamp (n T) | |
|---|---|---|---|---|---|
| | | | | | Row 1 |
| | | | | | Row 2 |
| | | | | | Row 3 |
| | | | | | Row 4 |
| | | | | | Row 5 |
| | | | | | Row M |

Package Data Buffer (FIFO)

Fig. 19

Columns →

Rows ↓



Camera Pixel Data Buffer
pixel indices (i,j,)

Fig. 20

Zoom and Focus Lens Group Position
Look-up Table

| Distance from Camera H (mm) | Zoom group distance (mm) Y (Zoom) | Focus group distance (mm) Y (Focus) |
|---|---|---|
| 1000 | 21.57489228 | 2.47E-05 |
| 1100 | 19.38089696 | 10.99009783 |
| 1200 | 17.10673434 | 20.65783177 |
| 1300 | 14.77137314 | 29.10917002 |
| 1400 | 12.39153565 | 36.47312595 |
| 1500 | 9.979114358 | 42.87845436 |
| 1600 | 7.540639114 | 48.44003358 |
| 1700 | 5.078794775 | 53.25495831 |
| 1800 | 2.595989366 | 57.40834303 |
| 1900 | 0.099972739 | 60.98883615 |

(use interpolation techniques for values distances between listed points in table)

FIG. 21

* note: a focal distance of zoom (eff. focal length) t. zoom lens are coupled (interdependent) in this camera embodiment.
※ fixed aperture FSb

Camera has a

## Focus and Zoom lens movement vs. working distances



$y = 1.34870140E-17x^6 - 1.20593022E-13x^5 + 4.41176738E-10x^4 - 8.26465964E-07x^3 + 7.66947276E-04x^2 - 1.80415530E-01x - 9.41364873E+01$
$R^2 = 9.99999987E-01$

FOCUS

ZOOM

$y = 2.84791608E-18x^6 - 2.35121504E-14x^5 + 7.84795370E-11x^4 - 1.33426085E-07x^3 + 1.16929778E-04x^2 - 6.85049995E-02x + 4.87609108E+01$
$R^2 = 9.99999989E-01$

lens movement(mm)

working distances(mm)

◆ zoom 1  ■ zoom 2 — Poly. (zoom 1) — Poly. (zoom 2)

← package height above conveyor

Conveyor belt

↑ above Conveyor belt

t (inches)

Conveyor-belt surface

FIG. 22

Photo-Integration Time Look-up Table

Distance from camera (package height above conveyor)
1000 (mm)

belt speed (package velocity)

10    600 feet per minute (FPM)

100 (mm)
10 FPM

Photo-integration time value that ensures square image pixels (1:1 aspect ratio)

FIG. 23

LOW RESOLUTION 2D CCD CAMERA (61)

HIGH RESOLUTION 2D CCD CAMERA (55")

25"

LDIP (122)

140

121

PACKAGE

CONVEYOR BELT

FIG 24

FIG. 25

192/206



Barcode

Image lift

Image Processing
Computer for
Barcode Symbol
Recording and
OCR Processing

21

Video
Image and
Cropped Image
strips

PLI A

6A

Local Cartesian
Coordinate System

CAMERA
(sample FOV)

///

55

PLI A

6B

Focus (t+dt)/

Zoom (t+dt)/

Photo Integration Time

22

Camera Control
Computer

Magnitude of (Polar-referenced)
Range-map data
specifies surface
reflectivity

LAN

Velocity (t)

Intensity (t)

Height (t)

Width (t)

Length (t)

122

4DIP
Subsystem

Local Polar
Coordinate System

Low resolution
2D CCD Camera
Subsystem

61

25''

FIG. 26

140

**570**

Top PID unit

**120**

**122**

Camera Field of View

Dimensioner Field of View

**120**

Right PID unit

**120**

**571A**

Left PID unit

**573**

**120**

**571B**

Bottom PID unit

**571**

Encoder

**576**

PID: Package Identification and Dimensioning unit

FIG 27

(TCP/IP) Remote Diagnostics over WWW

Control Ethernet Hub

**575**

**570**

**122**

**120**

LDDY Dimensioner

Top (Master) PFD Camera Control Computer

Camera

**55"**

**22**

Parcel Start/Stop
Left Edge, Right Edge, Height every 10 ms

Camera Data, 80 MBytes/sec

Camera

**55"**

**22**

Left CCD Camera Control Computer

**120**

Camera Data, 80 MBytes/sec

**572**

Camera

**55"**

**22**

Right CCD Camera Control Computer

**120**

Camera Data, 80 MBytes/sec

Camera

**55"**

**22**

Bottom CCD Camera Control Computer

**120**

Camera Data, 80 MBytes/sec

Encoder

**576**

(tachometer) EXTERNAL

FIG. 28

Parcel ID
Remote Diagnostics

Control
Ethernet
Hub
575

120

Dimensioner
Camera
122

Top (Master)
CCD Camera
120

55"
122

Parcel ID, Parcel Start/Stop
Left Edge, Right Edge, Height every 10 ms

35"
22

Camera

Left
CCD Camera
120
22

577

Data
Ethernet
Switch

Ethernet over
fiber optical
communication
medium

55"
22

Camera

Right
CCD Camera
120

572

35"
22

Camera

Bottom
CCD Camera
120

Encoder    570

570

Barcode Data,
4 x 1 kBytes
Binarized Image Data,
4 x 100 kBytes

Keying
workstation
580

FIG. 29

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CCD Camera-Based Tunnel System
Employing Package Coordinate Data
Driven Method of Automatic Camera
Zoom and Focus Control

570

(Slave unit #2)
$R_{Local 2}$

571A
573
Camera
Field of
View

571B
(Slave unit #3) $R_{Local 3}$

Master unit
120 (122)

$R_{Local 0}$

Package dimensioning
subsystem
&
Package
velocity
Detection
subsystem

Dimensioned Field of View

$R_{Local 1}$
(Slave unit #1)

$R_{global}$

576

Encoder

Camera Field of View

Package

$R_{Local i}$

Package coordinate data $\parallel R_{global}$ $\xrightarrow{H_G}$ Package coordinate data $\parallel R_{Local i}$

FIG.31

For each package transported through tunnel system, master unit (with package dimensioning subsystem and velocity detecuon subsystem) generates package height, width, length and velocity data $\{H,W,L,V\}_G$, referenced with respect to global coordinate reference system $R_{global}$, and transmits such package dimension data to each slave unit downstream, using the system's data communications network. — A

Each slave unit receives the transmitted package height, width and length data $\{H,W,L,V\}_G$ and converts this coordinate information into the slave unit's local coordinate reference system $R_{local\ I}$, $\{H,W,L,V\}_I$ — B

The camera control computer in each slave unit uses the converted package height, width, length data $\{H,W,L\}_I$ and package velocity data to generate camera control signals for driving the camera subsystem in the slave unit to zoom and focus in on the transported package as it moves by the slave unit, while ensuring that captured images having substantially constant O.P.I. Resolution and 1:1 aspect ratio. — C

( A )

FIG. 32A

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Each slave unit captures images acquired by its intelligently controlled camera subsystem, buffers the same, and processes the images to decode bar code symbol identifiers represented in said images, and/or to perform optical character recognition (OCR) thereupon. — D

The slave unit which decodes a bar code symbol in a processed image automatically transmits a package identification data element (containing symbol character data representative of the decoded bar code symbol) to the master unit (or other designated system control unit employing data element management functionalities) for package data element processing. — E

Master unit time-stamps received package identification data element, places said data element in a data queue, and processes package identification data elements and time-stamped package dimension data elements in said queue to link each package identification data element with one said corresponding package dimension data element. — F

FIG. 32B

FIG. 33A



FIG. 33B

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590

587

586B

125 Product Detection Subsystem

111 PACKAGE HEIGHT/WIDTH/LENGTH PROFILING SUBSYSTEM

101 PACKAGE VELOCITY MEASUREMENT SUBSYSTEM

IMAGING, DETECTION AND DIMENSIONING SUBSYSTEM (101)

System Control/Management Computer 590

I/O SUBSYSTEM 127

1D, CCD SUBSYSTEM 25 582

132

USER

Host Computer 1532

587 Electronic Produce Weight Scale

589 Host Computer System (Cash Register)

588

586A

58?

2

1A Image Capture and Buffering and HW Processing 21 Image Size

PLA

CAMERA 23 3" Video Image and Cropped Image size

6B PLA

22 Camera Control Computer

Velocity Intensity Index

Magnitude of Order received Response given upon section reflection

Four Clock Zonal Index Pixel Data Element Time

25'

I/O Sub 127

Net CMR 132, 127

Network-Communication Medium

FIG.33C

FIG. 34A



FIG. 34B

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FIG. 34C

Planar Laser
Illumination
Beam 621
(PLIB)

626

624

"PLIM on Semiconductor
Chip "
620

622

625

Surface Emitting
Laser (SEL)

623 Package

FIG. 35A

620 →



626

624

625

FIG 35B

FIG. 36A

FIG. 36B

FIG. 36C

FIG. 37

Composite PLIB from i-th
Linear SEL array (370)

371

362

3D FOV

365

361n

360

366

364A

367

364

FIG. 38A



360

372

364

362

363

368  364

364A

369

FIG. 38B